Relationship of Mass to Girth in Raccoons, *Procyon lotor* (Mammalia: Procyonidae), from West Tennessee

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ABSTRACT--Mass to girth ratio of 103 captured, adult (>14 months) raccoons (*Procyon lotor*) was analyzed to assess allometric relationships. Use of this ratio as a measure of physical condition was investigated with linear regression and a comparison of the ratio by year, season, sex, and age. There was no statistically significant difference among years ($F = 0.17$; $P = 0.8473$) or between seasons ($F = 1.13$; $P = 0.2916$). The ratio differed significantly among ages and was smallest for raccoons 14 to 38 months in age ($F = 12.31$; $P = 0.0001$). Males exhibited a significantly larger ratio than females ($F = 25.03$; $P = 0.0001$). There was no difference found within all groupings in parallelism or coincidence based on the regression equations. The regression equation for mass to girth for all individuals was Mass = 0.02916 * (Girth) - 5.5904 ($r^2 = 0.8044$; $P = 0.0001$). Although the allometric relationship between the mass and girth of raccoons was significant, this relationship does not appear to be indicative of the physical condition of the animal.

Estimating fitness of individuals in a population requires direct count of the reproductive success of the females or some other measure of physical condition such as antler beam diameter of white-tailed deer (*Odocoileus virginianus*)(Halls 1984), or kidney fat index of white-tailed deer and raccoons (*Procyon lotor*)(Johnson 1970, Glenn and Clark 1990). When studying medium-sized nocturnal mammals, it is difficult to accurately determine the number of offspring produced per female in live animals because typical measures of physical condition (such as placental scar counts, body fat indices, kidney fat indices) involve sacrificing the individual (Johnson 1970, Sanderson and Nalbandov 1973, Glenn and Clark 1990). In long-term population and community ecology studies, sacrificing individuals is not a suitable method. Thus, a nondestructive method of quantitatively reporting physical condition is needed.

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The inherent relationship known for mass and length (Thompson 1961, Schmidt-Nielsen 1984), suggests that a relationship between mass and girth could be an estimable parameter to investigate as a measure of physical condition. The girth of an animal could increase disproportionately to overall mass if there is a great amount of fat in relation to the skeletal and muscular tissue. This would indicate an improvement in the relative condition of an individual. Conversely, a decrease in girth measurement would likely be noticed before a large decrease in mass due to the loss of fat around the thoracic region, the first fat to be lost during a shortage of food (Stuewer 1943). Bissonette and Csech (1938) found smaller litters were produced by malnourished female raccoons, suggesting a possible correlation of mass to girth with reproductive fitness in raccoons.

No indirect method of estimating physical condition that avoids sacrificing individuals has been described for the raccoon. The objectives of this study were to investigate the allometric relationship between mass and girth in raccoons and to evaluate the suitability of this relationship as an indirect method of quantifying physical condition in this species.

STUDY AREA AND METHODS

The study was conducted on the 252 ha Edward J. Meeman Biological Station (MBS) located ca. 20 km north of Memphis, Tennessee, 35°20'N latitude and 90°01'W longitude. Tree species are described as western mixed mesophytic forest (Braun 1950, Miller and Neiswender 1987). Five permanent ponds, one temporary pond and permanent and intermittent streams provided water sources to MBS. No trap site was located at a distance greater than 450 m from permanent water. Topography varies from gentle (<3%) to steep (>45%) slopes. Climatic conditions varied greatly throughout the three years of the study. Rainfall at MBS from April to September was 77.4 cm in 1991, 50.9 cm in 1992, and 48.9 cm in 1993, and from October to March was 71.2 cm in 1991, 52.7 cm in 1992, and 26.2 cm for October and November 1993. Mean temperature did not vary greatly from the 30-year mean temperature at MBS. Mean seasonal temperature was 16.5 C in spring, 26.6 C in summer, 17.3 C in autumn, and 6.0 C in winter. There was an extended period equal to 30 days of >32 C daytime temperature from July to August 1993 that did not occur during the previous two years. Detailed analyses of the habitat and climatic patterns at MBS can be found in Ladine (1995).

Beginning 3 February 1991 and running through 30 November 1993, a 5 X 10 trapping grid was established with folding Tomahawk live traps (Tomahawk Live Trap Co.; Tomahawk, Wisconsin) placed 150 m apart (grid size = 112 ha). Traps were open four nights per week from 3 February 1991 to 31 January 1992, after which they were open three nights per week. Traps were baited with canned cat food.

Captured raccoons were anesthetized with a 1:1 mixture of ketamine hydrochloride (Ketaset; Bristol Laboratories, Syracuse, New York) and acepromazine maleate (PromAce; Ayerst Laboratories, New York, New York), based on estimated body mass, then tagged in both ears with No. 3 Monel ear tags (National Band and Tag Co., Newport, Kentucky). Data collected from captured raccoons included mass, girth, and age. Raccoons were weighed at the site of capture to the nearest 0.1 kg with a spring loaded scale. Girth measurements were taken at the posterior end of the sternum immediately anterior to the xiphoid process with a flexible tape pulled taught against the raccoon. Age was determined by tooth wear (Grau et al. 1970). Age classes were: 0-14 months (Age I), 14-38 months (Age II), 38-56 months (Age III), 56-84 months (Age IV), and >84 months (Age V).

Only adult raccoons, age II and older, were included in the analysis to avoid confounding relationships due to different patterns in growth for younger animals (Johnson 1970). To maintain independence of observations, only the first capture of an individual was used in data analysis, except for analysis of individual variation. Date of capture was categorized into two seasons, summer (April through September) and winter (October through March). Data were analyzed by year, season, age, and sex.

All data were analyzed using Statistical Analysis Systems (SAS Institute 1989). Comparison of the mass to girth ratio was analyzed with General Linear Models (PROC GLM) using Tukey's multiple comparison procedure to test among classes. The relationship between mass and girth was analyzed using linear regression (PROC REG). Because of the possibility that the allometric relationship may differ among age classes, years, or between sexes and seasons, parallelism and coincidence of the regression equation of the allometric relationship between mass and girth were tested within each grouping. Parallelism tests for the equality of the slope of the equation for more than one population. Coincidence tests for the equality of the intercept of the y-axis of the equation. Dummy variables were created to test for parallelism and coincidence for the three years of the study, each season, the four adult ages, and sex.

To investigate the stability of the allometric relationship, the linearity of the mass to girth ratio was examined with PROC REG for individuals with >5 captures. This analysis was used to determine if the allometric relationship exhibited temporal variation among individuals.

RESULTS

One hundred and five raccoons (61 males, 42 females) were measured. There was no difference among years ($F = 0.17$; $P = 0.8473$), or between seasons ($F = 1.13$; $P = 0.2916$). Differences in the mass to girth ratio were found among age classes ($F = 12.31$; $P < 0.0001$) and between sexes ($F = 25.03$; $P < 0.0001$). Age class II raccoons exhibited a smaller ratio than did the three older age class-

es (Table 1). The ratio was larger in males than females. There was no two-way interaction for SEX X AGE ($F = 1.08$; $P = 0.3622$), SEASON X AGE ($F = 0.97$; $P = 0.4118$) and SEASON X SEX ($F = 3.36$; $P = 0.0709$).

Table 1. Mass to girth ratio for year, season, sex, and age for captured raccoons (Procyon lotor). See text for explanation of age classes and definition of seasons.

Grouping		n	Mean
Year			
	1991	40	1.27:1.00
	1992	31	1.25:1.00
	1993	32	1.24:1.00
Season			
	Summer	44	1.14:1.00
	Winter	59	1.16:1.00
Sex			
	Males	61	1.27:1.00*
	Females	42	1.05:1.00*
Age class			
	II	37	1.01:1.00*
	III	38	1.32:1.00
	IV	22	1.22:1.00
	V	6	1.23:1.00

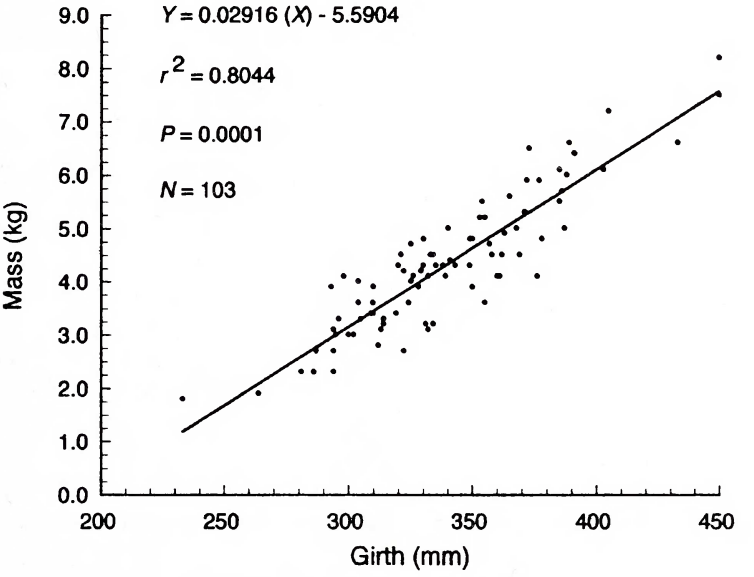
* Means are different within grouping ($P < 0.05$).

There was no difference between sexes in either parallelism ($F = 0.00002$; $P = 0.9964$) or coincidence ($F = 0.0407$; $P = 0.9601$). There was no difference among ages for either parallelism ($F = 0.0105$; $P = 0.9985$) or coincidence ($F = 0.0277$; $P = 0.9998$), between seasons for parallelism ($F = 0.0365$; $P = 0.8489$) or coincidence ($F = 0.0407$; $P = 0.9601$), and among years for parallelism ($F = 0.0173$; $P = 0.9829$) or coincidence ($F = 0.0216$; $P = 0.9957$).

Because there was no difference in parallelism or coincidence regardless of grouping, all data were analyzed in a single regression equation (Fig. 1). The regression equation, was significantly linear (Mass = 0.02916 * (Girth) - 5.5904; $r^2 = 0.8044$; $P = 0.0001$) and indicates a strong positive relationship between mass and girth. The lack of difference for either parallelism or coincidence indicate that the equation is useful across all age and sex classes regardless of season or year.

Thirteen raccoons were captured 5 or more times for analysis of individual variation in the mass to girth ratio. The stability of the allometric relationship between girth and mass exhibited substantial variability in correlation and linearity (Table 2). Only three raccoons showed a linear correlation between girth and mass during their capture histories. One female (4160M) exhibited a significant linear correlation without a strong fit of the data to the line indicating little relationship between mass and girth for this individual.

Fig. 1. Linear relationship between mass and girth of raccoons captured in western Tennessee from February 1991 to November 1993.



DISCUSSION

Several studies have shown a relationship between length and mass when length is converted to a volumetric measure (see Johnson 1970, Dunn and Chapman 1983, Vogel 1979, Schmidt-Nielsen 1984). The mass of an animal is believed to be approximated by volume, thus, the reason comparing mass to the cubed length of and animal. Because girth is a circumgeal measurement, a closer aproximation to mass may be achieved. The relationship between mass and girth has been shown for phocid seals (Hofman 1975, Castellini and Kooyman 1990) and dromedary camels (Camelus dromedarius) (Schroter et al. 1992).

Due to the manner in which most subcutaneous fat is accumulated in raccoons (Stuewer 1943), girth should vary in relation to mass. Regression analysis indicated that this occurred. Additionally, the mass to girth ratio was

linearly constant regardless of year, season, and sex class, with slight differences among age classes. The lower ratio for age II raccoons might indicate that these individuals are not able to accumulate the fat reserves of older animals resulting from potential lower dominance status. The potential for dominance hierarchies in raccoons has been shown experimentally (Barash 1974).

Table 2. Correlation of mass and girth of 13 individual raccoons (Procyon lotor). See text for explanation of age class.

Raccoon	Age Class	Sex	Number of Captures	Adjusted R^2[a]	P
2760M	V	M	5	-0.1134	0.4923
4022M	III	M	8	0.7185	0.0049
4145M	II	M	10	0.9030	0.0001
5208M	II	M	5	-0.2968	0.7901
4080M	II	F	5	0.1993	0.3172
4083M	III	F	8	0.3829	0.0601
4090M	II	F	6	0.8742	0.0127
4100M	II	F	10	-0.0667	0.5269
4117M	IV	F	6	-0.0259	0.4130
4160M	IV	F	9	0.5973	0.0089
4186M	II	F	7	0.2152	0.1648
4188M	II	F	9	0.2329	0.1065
4190M	II	F	6	-0.0819	0.4746

[a] Adjusted R^2 was used due to the small sample sizes for each individual.

Sanderson (1950) noted that the strain of pregnancy and lactation have a marked effect on the mass of female raccoons. Thus, adult females would be expected to have lower fat reserves than adult males due to the stress of rearing young. Furthermore, the observed difference between the males and females might be due to potential physiological differences between the sexes, a potential social dominance of the males (see Barash 1974), or a combination of the two.

The seasonal variation observed in individuals could be due to seasonal mass changes. Raccoons are known to exhibit seasonal fluctuations in mass (Stuewer 1943, Mech et al. 1968, Moore and Kennedy 1985). As indicated previously, the mass to girth ratio in raccoons is a linearly constant relationship. Consequently, one would expect to see girth fluctuate with mass.

The assumption for using a mass to girth ratio as a measure of physical condition was: the greater the amount of fat the better the physical condition of a raccoon. This assumption is based on the manner in which subcutaneous fat is accumulated in raccoons (see Stuewer 1943). Body fat and kidney fat indices have shown some correlation of the amount of fat to physical condition for the species (Johnson 1970, Dunn and Chapman 1983).

My findings indicate that the mass to girth ratio was not indicative of physical condition in raccoons for several reasons. No difference in slope or intercept existed between any groupings for the equation relating mass to girth. Although a difference existed among age classes and between sexes, this difference can be explained by reasons other than physical condition. Further evidence of the shortcoming of the mass to girth ratio as an indicator of physical condition was the lack of any consistent relationship between the two variables when the relationship was tested for each individual. All individuals appeared to be in good condition when captured, and differences in the ratio probably only reflect individual variation and might not be indicative of physical condition.

Thus, I concluded that the mass to girth ratio was not a good indicator of physical condition. Nevertheless, because of need for determining physical condition during long-term population and community ecology studies, there remains a necessity to determine physical condition through nonintrusive methods.

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